

# 論文の内容の要旨

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Friction stir welding (FSW) has been widely used mainly for aluminum alloys. Friction stir welding can join dissimilar materials and materials that difficult to join by conventional fusion welding. Many tools were developed in FSW to improve quality of the joint and productivity. Friction stir welding with a bobbin type tool has advantages compared to that with a conventional tool such as no backing plate, eliminate the root flaw, low distortion of the welded plate, joining thick plate in one-process, etc. In this study, fatigue crack growth (FCG) behavior of FSWed aluminum alloys joint joined by using a bobbin type tool was studied. Effect of FSW processes as comparison between bobbin type tool and conventional tool, effect of alloy type in similar material joint and effect of materials combination in dissimilar materials joint on the FCG behavior has been investigated. The results obtained in this research work were presented in details classified as below chapters.

**Chapter 1: Introduction** - Background and fundamental topic related to this study, such as friction stir welding of aluminum alloys and fatigue crack growth behavior of metallic material were introduced. A brief of literature review on FCG behaviors of FSWed aluminum alloys joints, research requirements, objective of this study and scope of the present work were also presented.

**Chapter 2: Fatigue crack growth behavior of FSWed 5052 aluminum alloy joint joined with a bobbin type tool and its comparison with single-passed and double-passed conventional FSWed joint** - Effect of FSW processes on FCG behavior of FSWed joints was studied in this chapter in 5052 aluminum alloy. Fatigue crack growth behavior at weld nugget zone (WNZ) and heat affected zone (HAZ) in the joints joined by using a bobbin type tool was investigated by comparing to those in the joints joined by using a conventional tool with single-passed and double-passed FSW processes. Friction stir welding process with the bobbin type tool introduced higher heat input compared to FSW processes with the single-pass and double-pass. Different FCG behavior was found in the joints joined with different FSW processing. Fatigue crack growth resistance of WNZ and HAZ in FSWed joint with single-passed process by using a conventional tool was higher compared to those observed in the FSWed joint with double-passed process by using a conventional tool and a bobbin type tool. However, the differences in FCG curves due to different FSW processes and positions in FSWed joints were arranged into a single curve when crack closure effect was taken into account. Grain size in the WNZ was dominant on threshold stress intensity factor range. Intrinsic FCG resistance of the FSWed joints were the similar regardless of FSW process.

**Chapter 3: Fatigue crack growth behavior of FSWed 5052, 6N01 and 7N01 similar aluminum alloy joints joined with a bobbin type tool** - Fatigue crack growth behavior at WNZ and HAZ in FSWed similar material joints joined by using a bobbin type tool in 5052, 6N01 and 7N01 aluminum alloys were investigated and compared to that of the BM. Different FCG behavior

was found in FSWed joints with different aluminum alloys. The results showed that difference in FCG resistance was significantly observed in near threshold region, FCG resistance in WNZ of FSWed 5052 and 6N01 joints was lower than that in the BM and the HAZ. In contrast, FCG resistance in WNZ of FSWed 7N01 joint was higher than that in the BM and the HAZ. Difference in FCG behavior at different weld region was mainly due to difference in crack closure behavior in the FSWed joints. Grain size in the WNZ was dominant on threshold stress intensity factor range.

**Chapter 4: Fatigue crack growth behavior of FSWed 6N01-5052 dissimilar aluminum alloys joints joined with a bobbin type tool** -In this chapter, 5052 and 6N01 aluminum alloys which showed the similar FCG behaviors as shown in Chapter 3 were joined to FSWed 6N01-5052 dissimilar materials joint for investigating the effect of materials combination on fatigue crack growth behavior in the WNZ of the joint. FCG resistance in the WNZ of FSWed 6N01-5052 dissimilar materials joint was lower than that of the BMs and almost the same as that in WNZ of the FSWed 5052 and 6N01 similar material joints. In case of materials combination between two alloys which showed the similar FCG behavior in the joints, FCG behavior of the FSWed dissimilar materials joint was the similar with that of the similar materials joints in those alloys.

**Chapter 5: Fatigue crack growth behavior of FSWed 6N01-7N01 dissimilar aluminum alloys joints joined with a bobbin type tool** - In this chapter, 6N01 and 7N01 aluminum alloys which showed different FCG behavior as observed in Chapter 3 were joined to FSWed 6N01-7N01 dissimilar materials joint for investigating the effect of materials combination on fatigue crack growth behavior in the WNZ of the joint. Fatigue crack growth behavior in WNZ of the FSWed dissimilar aluminum alloys joints were investigated comparing to that of the FSWed similar aluminum alloy joints and the BMs. The result showed that the FCG resistance in WNZ of FSWed 6N01-7N01 dissimilar materials joint was higher than that observed in WNZ of FSWed 6N01 similar material joint, however, lower than that observed in WNZ of FSWed 7N01 similar material joint. Fatigue crack growth behavior of FSWed 6N01-7N01 dissimilar materials joint was influenced by combined effect of FCG behaviors of the both alloys joint. Difference in fatigue crack growth curves observed in WNZ of the dissimilar materials joints was smaller than difference in fatigue crack growth curves observed in different BMs when the curves were arranged by effective stress intensity factor range. Fatigue crack growth resistance in WNZ was the similar or higher than that of BMs for the similar and the dissimilar materials FSWed joints when crack closure effect was taken into account.

**Chapter 6: Conclusion** - General conclusions and recommendations for further work have been discussed and summarized.